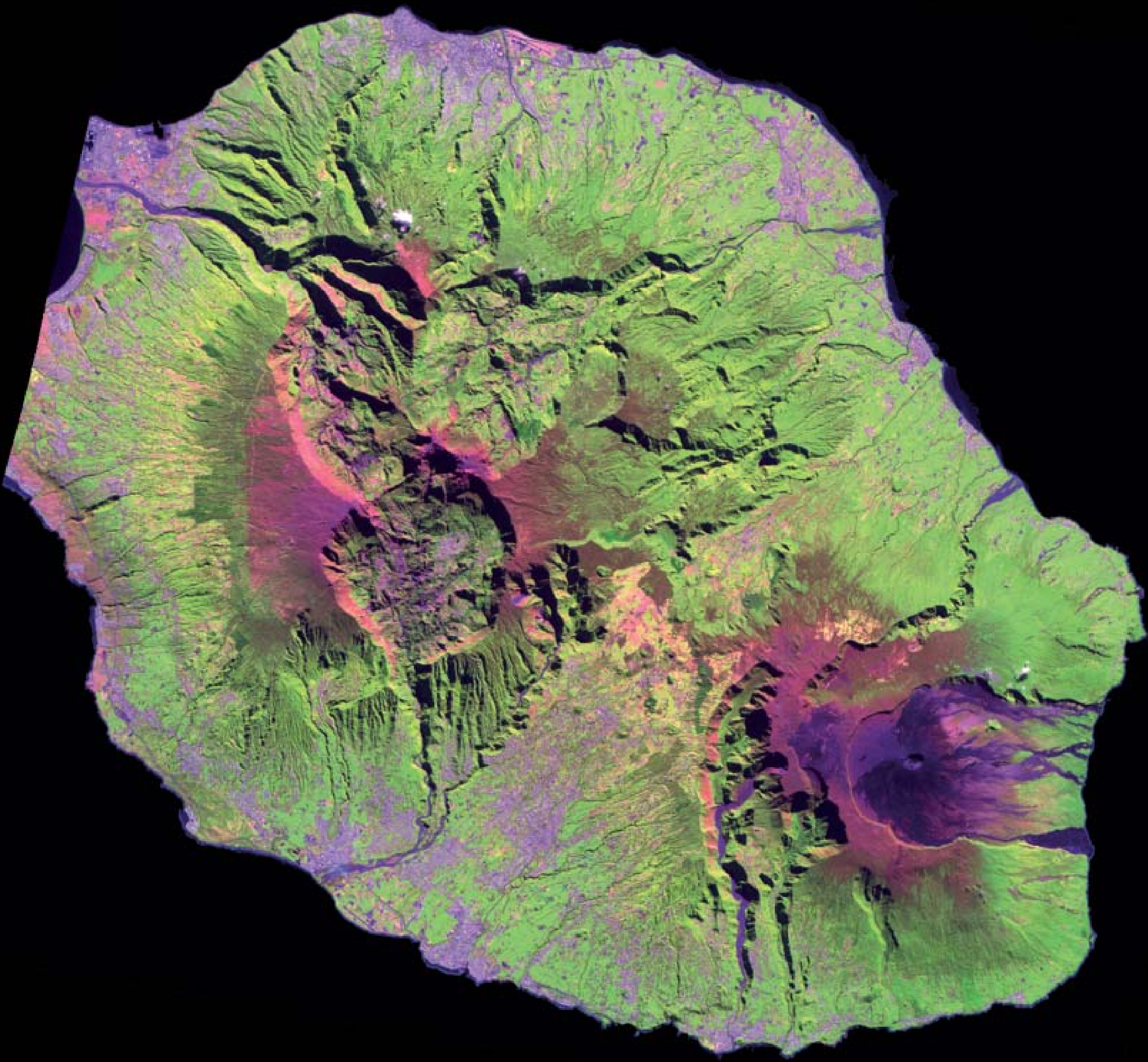


▲ *SPOT 4 image of 19/05/2009,*
Réunion island: false colour image (MIR/PIR/R), CNES Kalideos programme.

Satellite and airborne *remote sensing*

In 2009, around 60 satellites are seamlessly monitoring the Earth's atmosphere, oceans, and land surfaces. Satellite remote sensing has many advantages for environmental and territorial inventories and surveys as compared to conventional ground measurement systems (objectivity, homogeneity, repeatability, completeness, archiving, etc.). Acquired images and data are inputs for global surface process models while–on a more local scale–providing essential information for environmental and territorial resource management. The launching and development of new satellite and airborne systems has substantially enhanced the management of natural and agricultural areas. Specific innovative algorithms for image and signal processing are thus being developed in order to take full advantage of the technological potential of these systems.

■ **Light aircraft systems:** So-called 'light' data acquisition systems are currently being developed as a complement to 'heavy' satellite and airborne systems. With these systems, images are acquired via drone or microlight aircraft equipped with commercial digital cameras that have been modified for acquisition of images in spectral bands other than red/green/blue. These inexpensive and easy-to-use systems can generate images that require specifically tailored techniques to preprocess and convert them into quantitative thematic maps.

■ **Very high spatial resolution (VHSR):** Very high spatial resolution (metric and submetric) remote sensing systems first appeared around year 2000 for visible and infrared wavelengths (multispectral imaging) and 2008 for microwaves (radar imaging). Although initially limited to airborne acquisition, VHSR technology has radically changed satellite remote sensing and made it possible to map most landscape and urban environment constituents. Techniques implemented for object detection (extraction) and for splitting images into different entities (segmentation) are booming but, as the quality of the results may vary, adaptations may be required depending on the topic being investigated.

■ **Very high temporal resolution:** The scientific community and users can have access to time series images in low (100-1000 m) and, recently, decametric spatial resolutions, with a repeatability of around 1-3 days. Extraction of information from time-series images is a major future remote sensing challenge. Such work requires analysis and debate on time (season, year, etc.) and space (plant, plot, region, etc.) scales at which dynamic functioning, evolution and change phenomena are perceived and detected, and on tailoring models to these new data sources.

■ **Lidar techniques:** Lidar (light detection and ranging) is an observation technology system based on laser beam transmission-reception. Onboard range-finder systems determine the distance between the sensor and the target by analysis of the main lidar echo and may be applied to bathymetrical or topographical measurements. On the other hand, full wave form systems measure the entire reflected signal, thus providing access to the vertical structure of a target surface. They generate information that cannot be accessed by other remote sensing techniques, such as the digital terrain model in forested areas and 3D vegetation structure mapping.

■ **Radar techniques:** An essential feature of radar is its capacity to acquire images irrespective of the meteorological and sunlight conditions through active microwave transmission and reception of their echo after interaction with a surface. SAR radar imaging thus provides information on the surface roughness, radar altimetry generates information on ocean surface and continental water levels, while radar interferometry can be used to measure relief (spatial interferometry), movements and deformations (temporal interferometry) in soil and water.

The expertise pooled at Agropolis International in the fields of satellite and airborne remote sensing is highly original. There is substantial potential for developing remote sensing methods that could be mobilized to help in dealing with issues concerning environmental and resource knowledge and management, at regional and local scales in Europe and developing countries. The research teams thus invest in data acquisition, image and signal processing. They conduct studies directly associated with thematic fields of research, with support from the technological research platform of the Remote Sensing Center in Montpellier (France) and its development via the GEOSUD project.

Agnès Bégué (UMR TETIS)
& Frédéric Huynh (US ESPACE)

Satellite and airborne *remote sensing*

Main teams

UMR Géosciences Montpellier
(see page 28)

UMR ITAP - Information and Technologies for AgroProcesses
(Cemagref, Montpellier SupAgro)
32 scientists, with 12 involved in the research topic
Director: Véronique Bellon-Maurel, veronique.bellon@cemagref.fr
www.montpellier.cemagref.fr/umritap

UMR LISAH - Laboratoire d'étude des Interactions Sol – Agrosystème Hydrosystème
(see page 18)

UMR TETIS - Geoinformation and Earth Observation for Environment and Land Management
(Cemagref, CIRAD, AgroParisTech/ENGREF)
61 scientists involved in the research topic
Director: Pascal Kosuth, pascal.kosuth@teledetection.fr
http://tetis.teledetection.fr

UPR Functioning and Management of Tree-Based Planted Ecosystems
(see page 38)

US ESPACE - Expertise et SPatialisation des Connaissances en Environnement
(IRD)
50 scientists, with 45 involved in the research topic
Director: Frédéric Huynh, huynh@teledetection.fr
www.espace.ird.fr

Other teams focused on this topic

UMR AMAP - Botany and Computational Plant Architecture
(see page 18)

UMR HydroSciences Montpellier
(see page 18)

UR CoRéUs - Biocomplexité des écosystèmes coralliens de l'Indo-Pacifique
(see page 44)

Harnessing geoinformation to *enhance environmental* and territorial knowledge *and management*

The joint research unit (UMR) Geoinformation and Earth Observation for Environment and Land Management (UMR TETIS, Cemagref, CIRAD, ENGREF/ AgroParisTech) focuses on developing methods for acquiring and deploying geoinformation to enhance environmental and territorial knowledge and management. An integrated approach is thus implemented throughout the information flow channel, from the acquisition of data (mobilization) until the use of knowledge (appropriation), with the processing, production, management and pooling of geoinformation involved along the way.

The UMR TETIS research team conducts conceptual, methodological and thematic research to deal with the different components of this information flow channel, with four main lines of research:

➊ **Remote sensing, geoinformation acquisition and processing.** This research line is focused on satellite and airborne remote sensing methods applied to rural areas and territories in the domains of passive (visible, thermal) and active (radar, lidar) sensors. The research encompasses image and signal processing methods (classification, object detection, characterization of change, etc.). The UMR collaborates closely with CNES, space laboratories and industrial partners in this field, as well as with specialized research teams with the aim of adapting the methods to the specific features of the issues and systems under investigation.

➋ **Analysis of spatial structures and spatiotemporal dynamics.** This research line involves the analysis and mapping of spatial structures and spatiotemporal dynamics through a combined mathematical (geostatistics, spatial field reconstruction, spatial modelling of processes, etc.) and geographical (analysis of territorial dynamics, stakeholders' viewpoints, pictorial symbolization) approach. The research is focused especially on problems of spatial resolution, scaling consistency, measurement quality, model sensitivity, indicator development, and adaptation of computer languages for territorial modelling.

➌ **Information system design.** This information management, exchange and pooling research line deals with the structuring of spatiotemporal knowledge and information through the development of observatories and information systems. Studies are focused specifically on information modelling as well as concepts and methods for capitalizing, managing, archiving and providing access to information to be shared between stakeholders (data infrastructures, interoperability between information systems).

➍ **Information and territorial development.** This research line is focused on processes that facilitate the appropriation of information by stakeholders in territorial governance and development approaches. It deals with the role of information and systems that provide access to this information. Case studies are conducted in settings in which information is generally shared asymmetrically between stakeholders. The research is aimed at developing methods for hosting, coaching and training on information management. The goal is to ensure that the viewpoints, objectives and constraints of different social groups will be clearly expressed and taken into account by all concerned parties.

A fifth line of activity is devoted to training (representing around 20% of the UMR's activities): initial engineering training, MSc and PhD courses, continuing professional education, etc.

Approaches are developed in remote sensing, computer science, spatial analysis, geography, environmental science and territorial development. The UMR coordinates research projects and public policy support projects that concern agriculture, the environment, natural areas, forests, aquatic environments, animal health, territorial development and hazards.

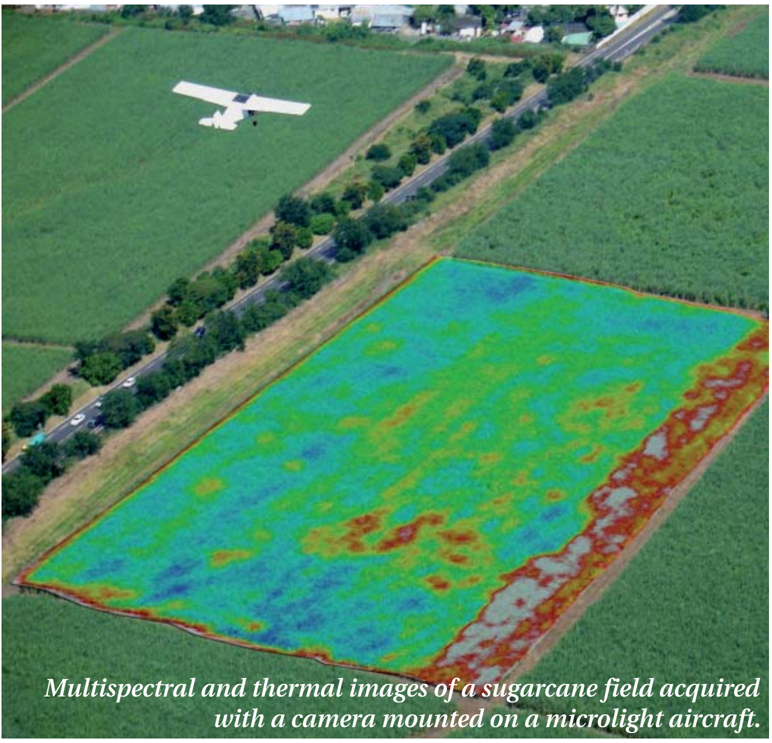
Earth Observation, integrated management *of environments and* societies, information *for territorial development* in tropical environments

The overall goal of the *Expertise et SPAtialisation des Connaissances en Environnement* unit (ESPACE, IRD) is to develop and implement methods for the spatialization of knowledge through remote sensing and integrated approaches, from data acquisition to decision-making processes, with the aim of promoting sustainable territorial development in tropical environments.

The scientific and technological activities of the unit are organized in the framework of three methodological research programmes:

- satellite Earth Observation for monitoring tropical environments: remote sensing based spatial indicators, near real time environmental observation and monitoring methods
- integrated approaches to environment and society: landscape analysis and observatories for environmental management, spatialization of environment-health risks; territorial governance indicators
- integrated knowledge systems to enhance decision-making support: interoperable information systems for sharing mixed (spatial and *in situ*) data, modelling of dynamics. •••

Development of light airborne image acquisition systems (visible and thermal IR bands): the AgriDrone project



Multispectral and thermal images of a sugarcane field acquired with a camera mounted on a microlight aircraft.

The aim of the AgriDrone project is to supply farmers in Réunion with sugarcane production management support tools to enable them to increase crop yields and reduce expenditures through efficient fertilization, irrigation, weeding and pest control.

These new tools are based on aerial photographs taken with commercial digital cameras. These cameras are equipped with band-pass filters through which only the desired wavelengths pass (e.g. near infrared). A thermal camera is also used to measure surface temperatures. These cameras are mounted on small unmanned aerial vehicles or ultralight-type aircraft that are ready for service upon request. Maps are drawn up on the basis of geoinformation obtained from the images. Spectral information from the images is correlated with the field data (plant nitrogen and water contents, leaf area, biomass, etc.) in order to clarify the link between the measured radiometric signal and the surface parameters, and to develop relevant agricultural indicators for the agricultural subsector. The tools developed within the framework of AgriDrone will ultimately enable users to gain insight into the actual situation on target farms (planted area, average field slope, heterogeneity, etc.), and to monitor crop development and growth anomalies (germination, weed infestation, water and nitrogen stress, etc.).

A comprehensive operational service is now available based on the methods and tools developed through this project: a catalogue of mapping products, a tool for disseminating and handling digital maps and teaching material for secondary schools and technical services.

This project is carried out by CIRAD in partnership with Cemagref, *Avion jaune* and CERF. It is supported by the French Ministry of Agriculture and Fisheries and the Réunion Region.

Contacts: Valentine Lebourgeois, valentine.lebourgeois@cirad.fr
& Bruno Roux, bruno.roux@lavionjaune.fr

SEAS-Guyane: a direct satellite data receiving technological platform for Amazonian territorial monitoring

Considering the exceptional uniqueness of the Amazon Basin, it is essential to have a satellite programming and data receiving capacity to enable the programming, processing and development of indicators that could be used to assess the environment in this specific area and thus enhance its management. The *SEAS-Guyane* (Survey of Environment Assisted by Satellites) project was designed to set up a technological platform for the acquisition and processing of data on different spatiotemporal scales from high-resolution satellites (SPOT and ENVISAT) to be used for research, training and regional development.

Through this platform, users have access to quasi-daily data at a spatial resolution ranging from 20 to 2.5 m within a 5 000 km diameter circle focused on French Guiana and spanning the Guyana Plateau, West Indies and Amazon Basin. Over 14 000 images are acquired annually within this circle, and over 500 images are generated for selected and labelled *SEAS-Guyane* projects.

The technological platform operational policy was drawn up by a steering committee (Regional Council, IRD, CNES, French government, SPOT Image, ESA, *Guyane Technopole, Pôle Universitaire Guyanais* [PUG], *Université des Antilles et de la Guyane* [UAG]) headed by the French Guiana Region and IRD. The ESPACE research unit (IRD), the project coordinator, has established partnerships with SPOT Image (station installation and operation), UAG (joint research team, training), PUG, CNES, ESA, *Guyane Technopole,* local communities and French government services to develop an international research platform for spatial remote sensing and monitoring of the Amazonian environment. The overall objective is to set up environmental observatories to foster sustainable development in French Guiana, the Amazon Basin and the West Indies.

SEAS-Guyane satellite image receiving station.

This project has given rise to many French, European and international research projects and pilot applications. For instance, the SEAS project has enabled France to work towards fulfilling its Kyoto Protocol commitments by acquiring an image mosaic to determine the state of its forests in this region in 2006 (*Institut Forestier National,* IRD, ONF, IGN, Cemagref).

Contacts: Frédéric Huynh, frederic.huynh@ird.fr et Michel Petit, michel.petit@ird.fr

The unit develops training activities: participation in Master's programmes, individualized training tailored to scientific network needs and management.

This service activity concerns:
■ operational management of a network of low-resolution and high-resolution data direct receiving stations (French Guiana, Montpellier, Réunion, Canary Islands, New Caledonia) so as to facilitate access to satellite data for research in developing countries, while also contributing to environmental observatory operation
■ access to spatial data infrastructures via a general interoperable information system platform in compliance with INSPIRE/OGC (Infrastructure for Spatial Information/Open Geospatial Consortium) standards.

The priority operational themes are:
■ Sustainable management of ecosystems in developing countries: geoinformation and sustainable management
■ Continental waters and coastal environments: resources and uses
■ Health security, health policies: the environment and emerging diseases
■ Development and globalization: enhanced governance for sustainable development
■ Renewable energy and territorial development.

The unit's research is based on permanent laboratories in France, in tropical French overseas regions and in other foreign countries and on a network of research platforms:
■ Remote Sensing Center (Montpellier, France), in partnership with Cemagref, CIRAD, AgroParisTech/ENGREF and the University of Montpellier Sud de France
■ French Guiana Campus (IRD-UAG-*Pôle Universitaire de Guyane*) in cooperation with Brazil on issues in the Amazon region
■ Campus for the Indian Ocean Region, Réunion University
■ New Caledonia (University of New Caledonia) for the South Pacific region.

International research is also carried out in collaboration with joint research teams and laboratories in Brazil and Africa. •••

a. Initial image
b. Fourier spectrum of the image: peak amplitude detection
c. d. e. Filtered images: highlighted vine plots corresponding to the three main detected peaks.

Vine-plot detection via Gabor filtering.

Vine-plot mapping using very high spatial resolution remote sensing

Very high resolution remote sensing–which can generate images with up to sub-metric resolution–has boosted the potential for agricultural land use mapping and inventory. Crop types can thus be now distinguished on the basis of their spatial structure, no longer just according to radiometric criteria.

UMR LISAH carried out a study aimed at acquiring geoinformation on surface features in vineyards on the basis of airborne remote-sensing images obtained at 25 cm resolution. The vineyards were successfully detected and the plot distribution patterns characterized. Within the framework of the European BACCHUS project, UMR TETIS and ITAP have developed a software tool for automatic detection of vine plots through airborne or satellite imaging, without any prior knowledge of the plot distribution pattern.

The automatic recognition and characterization sensing principle is based on Fourier spectrum analysis of images in which vine plots, due to their periodic structure, are identified by marked amplitude peaks. The tool automatically detects these peaks, which each correspond to a spatial frequency and a specific orientation. A highly selective filtering process (Gabor filter) is applied around each thus-determined frequency and orientation value. Only target vine plots are highlighted, so the edges of these plots can therefore be determined. The frequency and orientation values associated with each plot provide a very accurate measurement of the interrow distance and row orientations, which are crucial parameters from an agricultural standpoint. The plot characterization process is also focused on the detection of grassy interrow strips (additional frequencies in the Fourier spectrum), and on estimating the number of missing plants (statistical radiometric comparison).

The tool was assessed in a 200 ha study area (La Peyne catchment, Languedoc-Roussillon, France) from a natural colour (red, green, blue) aerial image, at 50 cm resolution, which was acquired via a microlight aircraft *(Société l'Avion Jaune)*. Around 80% of the vine plots were detected, or 84% in terms of surface area.

Contacts: Michel Deshayes, michel.deshayes@teledetection.fr
Gilles Rabatel, gilles.rabatel@montpellier.cemagref.fr
& Carole Delenne, delenne@msem.univ-montp2.fr

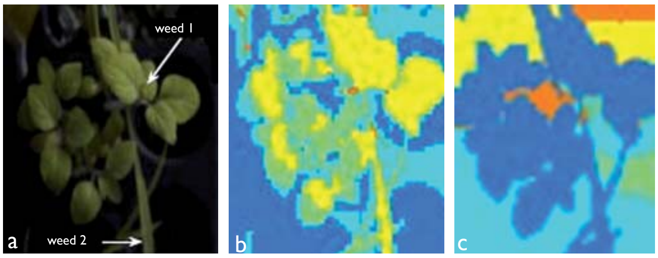
Processing hyperspectral images containing spectral and spatial information

Hyperspectral imaging (HSI) can be used to produce and analyse images of the same scene at a series of wavelengths within the same spectral domain. Such images generate information on the chemical composition of objects, which means that objects of the same apparent colour but with a different chemical composition can be differentiated.

Most standard hyperspectral image processing methods analyse data without taking spatial information into account. Pixels are thus processed individually as a single array of spectral measurements without any particular spatial arrangement by using various classification methods (k-means, fuzzy-C-means, hierarchical classification, support vector machines, etc.).

The combined use of available spectral and spatial information for object detection, which has been promoted by the advent of high spatial resolution hyperspectral imaging devices, etc., now seems essential for many application domains (characterization of urban areas, agriculture, etc.).

This is especially useful for processing images with complex contents, where the objects to differentiate are very spectrally close while having different spatial features (e.g. in shape, compactness, etc.).



▲ ***Results obtained with an HSI image of a natural vegetation scene (160 spectral bands, 400-1000 nm).***
(a) Original image (multispectral).
(b) Result obtained with an approach that disregards contextual information (k-means, 5 classes).
(c) Result obtained with a spectral-spatial approach: the vegetation is clearly differentiated from the surrounding environment.

UMR ITAP is focusing on this issue and has thus developed a spectral-spatial cooperation scheme to split images into spectrally homogenous adjacent regions (segmentation). The two dimensions (spectral, spatial) are studied separately and simple tools designed for specific environments are used. These are chemometric tools (spectrum processing tools) for the spectral domain, and image segmentation tools for the spatial domain. These tools can be used to extract relevant spectral and spatial structures and are iteratively implemented to achieve optimal image segmentation.

Contact: Nathalie Gorretta,
nathalie.gorretta@montpellier.cemagref.fr

Development of sensors and decision-support systems

The joint research unit (UMR) ITAP Information and Technologies for AgroProcesses (Cemagref, Montpellier SupAgro) aims to develop equipment to enhance agricultural sustainability. The team conducts studies on sensors and decision support systems and on environmental technologies in agriculture. The main research topic, i.e. sensors and decision-support systems, includes proxy-detection remote sensing, traceability and information processing/modelling.

UMR ITAP conducts research to develop optical sensors (artificial vision, hyperspectral vision, UV & near-infrared spectrometry). It is striving to develop decision support systems to assess the status of different systems or to develop precision agricultural approaches. Different methods are thus studied and implemented: fuzzy logic, discrete event systems and geostatistics. The goal is to characterize agrosystems and agroproducts. Finally, it develops systems to ensure the traceability of agricultural operations, especially spraying, with the traceability data being subsequently used to improve such operations. Vine cropping is the main field of study, but other crops, including fuel crops, are also covered.

In the sensor field, research is conducted on new optical devices that could be used in harsh environments (outdoor and industrial environments). UMR ITAP has developed advanced know-how on portable or online near-infrared sensors that can be used for the analysis of organic product compositions. In addition to material sensor developments, the measurement problem also concerns robustness. UMR ITAP is recognized worldwide for its chemometric expertise, which is specifically oriented towards boosting measurement robustness. Finally, the focus is also on hyperspectral vision research and especially on designing innovative hyperspectral image processing methods that take advantage of the team's image analysis and chemometry expertise.

UMR ITAP also concentrates on developing decision support systems for managing agricultural operations.

The unit is developing methods and adapted tools. The methods are based on fuzzy logic and enable users to come up with rules on the basis of data and/or expertise for mapping phenomena or building indicators, all of which may be spatialized or not. The methods also involve geostatistics, which are applied to high resolution viticulture data (precision viticulture). The aim is to delineate homogenous areas in which it would be appropriate to apply a specific operation. Finally, the formalization of decision processes is approached via discrete event systems.

The main research framework of UMR ITAP is precision viticulture. The VINNOTEC project (funded by FUI, FEDER, LR Region, labelled by the Q@LI-MEDiterranée competitive cluster) is highly emblematic, with Cemagref serving as the scientific partner. VINNOTEC fosters the contribution of information and communication technologies (ICTs) in developing vineyard products tailored to meet market expectations. UMR ITAP is involved in the development of portable, online or airborne sensors in near infrared spectroscopy, in artificial vision, along with the processing of data acquired through sensors with the aim of developing indicators and rules of conduct.

UMR ITAP also proposes different training on this topic. It is especially responsible for the specialized training programme 'AgroTIC: ICTs for agriculture and the environment' at the Master's level at Montpellier SupAgro (France). ■

Potential of L-band radar imagery for studying tropical forest dynamics: the international ALOS Kyoto & Carbon Initiative

Through the international Kyoto & Carbon Initiative, the Japan Aerospace Exploration Agency (JAXA) is backing an international scientific initiative aimed at developing reproducible forest ecosystem monitoring methods. These could, for instance, generate a quantitative database that could be tapped to help reduce carbon emissions due to environmental degradation and deforestation. It is essential to pre-evaluate forest parameters contributing most to the signal measured in images so as to be able to extract information on the distribution of plant biomass in the 3D space and to monitor potential changes under the forest canopy.

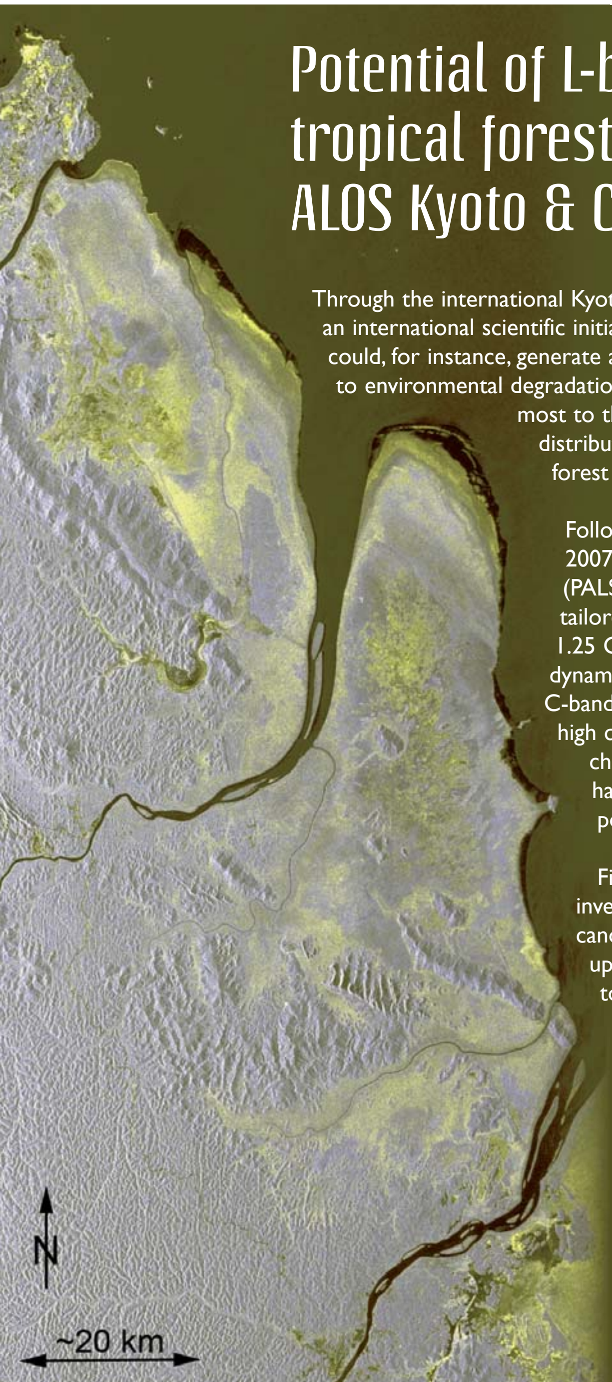
Following the launching of the Advanced Land Observing Satellite (ALOS)* in January 2007 and thanks to the availability of Phased Array type L-band Synthetic Aperture Radar (PALSAR)** data, it is now possible to reanalyse tropical forest structuring through a tailored instrumental configuration. First, surveying forests with L-band radar, i.e. with a 1.25 GHz signal (λ wavelength = 23.6 cm), enables more efficient assessment of forest dynamics, with radar signal saturation occurring at a 3-fold higher biomass level than with C-band radar (150 t/ha of dry matter as compared to 50 t/ha). Secondly, because of the high quality radiometric calibration of PALSAR data (<±1 dB), reproducible methods for characterizing forest resources may be developed on the basis of still images. Thirdly, having access to images that are unaffected by cloud cover will boost the operational potential for imaging in tropical regions.

Finally, the estimation of tropical forest parameters on a regional scale by statistical inversion of properly calibrated L-band radar signals could likely be improved. Forest canopy texture could be analysed on metric resolution optical images in order to come up with estimations that could serve as benchmarks for forest stands as a supplement to field measurements.

Contact: Christophe Proisy, christophe.proisy@ird.fr

For further information: www.eorc.jaxa.jp/ALOS/en/kyoto/kyoto_index.htm

* A Japanese satellite that was developed for mapping, regional land-coverage observation, disaster monitoring and resource surveying.
** a radar system capable of acquiring data with up to 10 m resolution.



◀ L-band ALOS PALSAR image of the coastline of French Guiana between Cayenne and the Oyapock estuary (colour composite image with HH and HV polarization): at low tide, the bare mudbanks (black) appear to be smooth at 20 cm wavelength; mangrove saplings (greenish-brown) can be distinguished from older mangroves and forests with more substantial biomass (grey).

Mapping and monitoring tropical plantations by remote sensing

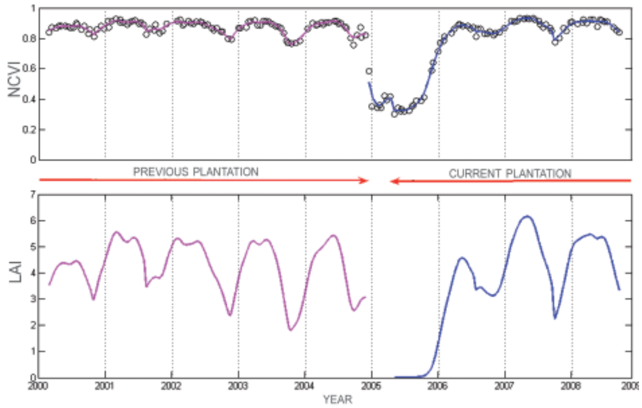
The productivity of planted tropical ecosystems must be increased in the long term, while avoiding negative impacts on the environment, in order to meet growing market needs. Environmental and climatic conditions as well as current and previous cropping practices could, however, have a major lasting impact on the evolution of biophysical and biogeochemical components of planted tropical ecosystems. It is essential to quantify these factors.

The CIRAD internal research unit (UPR) Functioning and Management of Tree-Based Planted Ecosystems focuses research on characterizing and formalizing water, carbon and mineral cycling within tropical plantations. An ecosystem-based approach is implemented to gain insight into the relevant plant-soil-climate interactions.

Satellite imaging is an efficient tool for spatiotemporal monitoring of plantations. Specific sensors with suitable spatial, temporal and spectral properties are required for studying particular ecosystem features. The satellite information collected cannot be used without processing, i.e. different treatments involving geographic information systems (GIS) and complex models are required.

Some structural and physiological characteristics of plantations that can be estimated via satellite imaging are:

- leaf-area index (quantity of leaves on the plantation)
- vegetation biomass
- chlorophyll content
- productivity.



▲ *Use of a satellite signal (NDVI, black circles) to estimate leaf-area index (LAI) patterns on a eucalyptus plot in Brazil.*
Annual declines correspond to dry season leaf shedding.

These characteristics can then be analysed spatially (differences between plots) and/or temporally (plot changes over time). For instance, information on temporal changes in the leaf-area index in plantation stands can reveal the duration and intensity of water stress (see above graph). Spatial information can highlight differences in fertility or the water storage capacity of the soil during the dry season.

All of this information can then be used to fit ecosystem functioning models on a plot scale or for a set of plots. These models can be implemented, for instance, to assess the sustainability of carbon or mineral stocks in plantations.

Contacts: Guerric le Maire, guerric.le_maire@cirad.fr
Claire Marsden, claire.marsden@cirad.fr
& Yann Nouvellon, yann.nouvellon@cirad.fr

Lidar mapping of vegetation, landscape and surface water

© A. Jacome

▲ *Left: panoramic photograph; Right: 3D point cloud obtained by terrestrial lidar.*

Lidar (light detection and ranging) technology involves an active remote sensing sensor based on a laser impulse transmission-reception principle. Lidar, which is conventionally used in topometry and meteorology, shows promise for characterizing continental and oceanic surfaces, especially from aerospace platforms. As lidar is capable of penetrating into environments such as water and vegetation, the information it generates can supplement other information obtained by radar and optical imaging. Signals from lidar sensors are processed on the basis of telemetry principles. This can generate accurate topographical data on natural environments, submerged or slightly submerged areas, along with a 3D description of the vegetation structure. A more complete form of the backscattered signal (a highly sampled waveform) can also be processed using suitable signal processing algorithms. Other target properties can then be extracted depending on the wavelengths used, e.g. the geometry and nature of the target (water turbidity, local slope, vegetation density, etc.).

Research carried out by UMR TETIS, LISAH and AMAP is focused on three thematic fields: vegetation characterization, hydrology and fine topography. The aim is to develop specific methods for processing lidar waveforms and lidar derived 3D point clouds and to qualify the data. Lidar signal modelling studies are also conducted in collaboration with CNES and commercial stakeholders to determine the specifications of sensors for future space missions. For vegetation studies, biomass is assessed and canopy and understorey structures are characterized since such information is crucial for sustainable management of forest environments (forest fires, biodiversity).
In hydrology, altimetric monitoring and bathymetric assessment of continental waters are carried out to improve management of water resources and aquatic environments. Another aim is to make effective use of detailed descriptions of areas imaged by airborne topographical lidar (dams, drainage systems) in order to improve descriptions of surface flows and to predict associated risks such as erosion.

Contacts: Jean-Stéphane Bailly, bailly@teledetection.fr
Jean Dauzat, jean.dauzat@cirad.fr & Sylvie Durrieu, sylvie.durrieu@teledetection.fr

© ESA - AOES Medialab

▲ *Document outlining the European Space Agency's scientific strategy for its Living Planet Programme (2006).*

Remote Sensing Center, GEOSUD and supporting space agencies and international Earth Observation programmes

Space agencies like the French *Centre National d'Études Spatiales* (CNES) and the European Space Agency (ESA) obtain support from the scientific community to develop concepts for satellite missions undertaken for scientific or operational purposes, to develop technologies upstream of sensors, to validate products derived from these missions, and to design methods that will enable operators to use these products for scientific or operational applications.

Researchers from the Remote Sensing Center (UMR TETIS, US ESPACE), based in Montpellier (France), participate in French, European and international scientific committees and initiatives:

- Science Programme Committee and Earth-Ocean-Continental Surface-Atmosphere Scientific Committee of CNES
- Earth Science Advisory Committee of ESA and GMES Programme of the European Commission and ESA
- International initiatives such as the Group on Earth Observation and the Integrated Global Observing Strategy.

Through this involvement, Agropolis International researchers strive to include concerns and challenges of agriculture, the environment, territories and sustainable development in strategies developed for satellite Earth Observation.

They have, in collaboration with laboratories and commercial stakeholders in France, elsewhere in Europe and other countries, helped to define and promote different satellite missions of CNES, ESA and the National Aeronautics and Space Administration (NASA):

- radar altimeter satellites (Topex Poseidon, Jason 1 and 2, ERS 1 and 2, ENVISAT) for measuring continental water levels
- the future PLEIADES satellite constellation for very high spatial resolution optical imaging
- the concept of the Surface Waters Ocean Topography mission for measuring continental water slopes by across-track spatial radar interferometry
- the concept of the OSCAR mission for measuring the surface velocity of rivers by along-track temporal radar interferometry
- the concept of the LVTH (lidar, vegetation, terrain, hydrology) mission for lidar measurement of 3D characteristics of forests, terrain and continental waters.

The Remote Sensing Center technology platform, and its development via the Geoinformation for Sustainable Development (GEOSUD) project, offers the scientific community and Agropolis International partners a suitable environment for research, training and knowledge transfer in the satellite Earth Observation field.

Contact: Pascal Kosuth, pascal.kosuth@teledetection.fr